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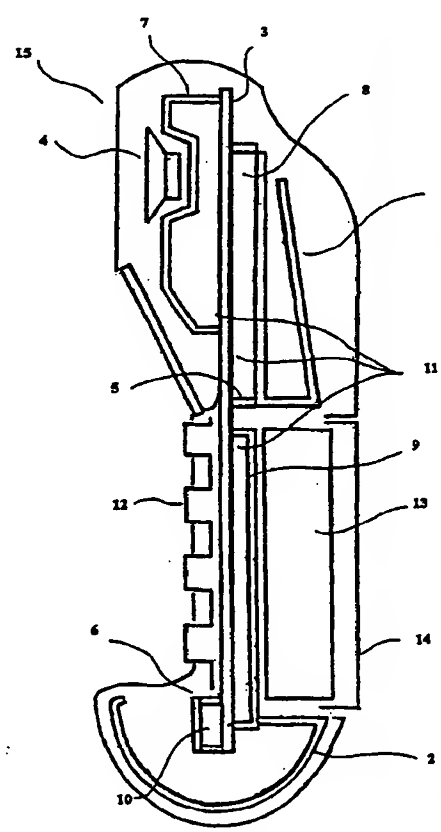
(54) Title: DUAL ANTENNA SYSTEM

(57) Abstract

The invention relates to a mobile communication device having a housing (15), said device comprising antenna means and signal processing means coupled with said antenna means, said antenna means comprising at least two antennas (1, 2) having different radiation patterns. An important advantage of the invention is that the device may automatically select an antenna (1, 2) having a suitable radiation pattern for a particular environment.



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DUAL ANTENNA SYSTEM

Field of the invention

The invention relates to a mobile communication device comprising at least two antennas.

Background of the invention

An increasing number of portable electrical equipment for wireless communication is being produced. Not only mobile phones, as in the preferred embodiment of the invention, but also cordless phones and laptop computers with electronic circuitry for transmitting and receiving EM-signals.

Each year, a new generation of portable electrical equipment is being introduced on the market.

In general, each new generation of portable electronic equipment becomes smaller than the previous one. As the equipment gets smaller, the distance between the handgrip of the equipment and the transmitting/receiving antenna herein, decreases. Therefore, all though the problem of user interference has always existed, the problem is now increasing.

Prior to this invention, it was generally accepted that portable electrical communication equipment had a poor connection under some circumstances. If, for example, a conventional mobile phone is laid on a metal surface or if a hand is held around the antenna, it is known to have a deteriorating effect on the radio connection. It is the

object of this invention to prevent or compensate for this deterioration.

Summary of the invention

When a mobile communication device having a housing, said device comprising antenna means and signal processing means coupled to said antenna means, said antenna means comprising at least two antennas having different radiation patterns, an advantageous device has been obtained.

Thus, the use of a selective radiation pattern provides the possibility of increasing the signal quality of the communication device, even if the device is used in critical environments with respect to transmission and reception.

Thus, the invention provides an efficient utilisation of multi-antenna systems as the antennas of the device may supplement each other, not only with respect to the different location within the housing of the device, but also with respect to the directivity of the antennas. One antenna radiation pattern may be suitable under certain transmission conditions, while another radiation pattern may be suitable under other transmission conditions.

If the hand of the user e.g. covers an antenna, another antenna may be situated at the other end of the handset and therefore uncovered. This advantage is of particular interest if the utilised antennas are directive.

An important aspect of the invention is that the signal quality and the implemented correction by means of at least two antennas are based on a recognition of the fact that both transmission and receiving conditions have to be evaluated and corrected.

Another important advantage of the invention is that both of the at least two antennas may serve for transmitting and receiving purposes. The result of the double function antennas is that the overall performance of the mobile device may be evaluated and adapted to certain receiving and transmitting conditions.

It should be noted that a mobile device according to the invention may not only detect undesired conditions when a user actually uses e.g. a handset, i.e. in certain kinds of active use. It may also detect and correct somewhat static undesired passive conditions, for instance if the handset is located on a table with metallic surface, or partly covered by the surroundings, and thus blocking for a quality transmission or receiving via the active antenna.

In a preferred embodiment of the present invention, the antennas are dual-band internal patch antennas, both operating at more than one band of frequencies.
In another embodiment of the invention, one or both antennas are implemented as external antennas where single or dual-band antennas are also a possibility.

In a particularly preferred embodiment of the invention, the directivity of the at least two antennas are in opposite directions. Under these circumstances, near optimal and power saving transmission and receiving is obtained as the signal transmission and receiving may be established in practically all directions around the device.

This complementary radiation mode thus provides optimal transmission quality with a minimum of power consumption in contrast to e.g. omni-directional antennas, which have to cover the total space around the mobile device, thus wasting power on unused radiation directions.

It should be noted that the invention may be implemented in a sequential manner in the sense that the receiving and transmitting quality may be determined dynamically after transmitting or receiving a burst.

It should moreover be noted that the algorithm measuring and controlling switching is relatively slow as the addressed signal quality is of a somewhat static character contrary to e.g. diversity techniques addressing fast changing receiving signal conditions at the receiving site.

The term "different radiation pattern" implies that e.g. the radiation field of the antenna may be different. A different pattern may thus be obtained by a combination of an omni-directional antenna combined with a directional patch antenna or for instance a combination

of two directional patch antennas having different orientation.

Another different radiation pattern may be obtained if two individual antennas are mutually spaced in the handset. Thus, a difference in radiation may be obtained in the sense that the antennas radiate dynamically in dependence of external local conditions. Conditions providing different radiation pattern may for instance be a total or partly covering of one of the antennas. Thus, a dynamic and mutual change of radiation between two antennas are thus obtained within the scope of the invention if the antennas are spaced and/or orientated differently.

Brief Description of the Drawings

Fig. 1 is a view of the preferred embodiment of a mobile communication device in accordance with the invention,

Fig. 2 shows a radiation characteristic of one directive antenna,

Fig. 3 shows a radiation characteristic of two directional antennas,

Fig. 4 shows a circuit diagram of the preferred embodiment of a mobile communication device in accordance with the invention,

Fig. 5 shows a flowchart of the algorithm selecting the transmitting antenna based on the transmission quality of that antenna, and

Fig. 6 shows a flowchart of the algorithm selecting the receiving antenna based on the receiving quality of that antenna.

Detailed Description

Fig. 1 shows a portable radio communication apparatus comprising a handset 15 having a housing 14, a keypad 12 and a display 16.

Inside the handset, a printed circuit board (PCB) 3 with the necessary electronic circuitry 16 is provided. Shielded boxes 7-9 protect the electronic circuitry.

Moreover, a microphone (not shown in fig. 1) is protected y a shielding box 10.
Electrically connected to the PCB 3 by shielding walls 5 and 6 are a first and a second antenna 1, 2 with the same operational frequencies. Also inside the handset and electrically connected to the PCB are a battery 13 and a loudspeaker 4.

The antennas 1, 2 are arranged at different positions and with different directivity inside the housing 14. The antennas are placed apart from each other in such a way that if one is being covered the other is most likely uncovered. E.g. if one antenna is placed faced down on a metal plate the other will be pointing upward. Also if one antenna is covered by the hand of the user, the other antenna will be placed at the other end of the handset 15, and therefore likely be uncovered.

Means for detecting the de-tuning effect of the antennas 1, 2 caused by the user's hand from the closeness of the user's head or other obstacles will be described in the following.

Thus, the invention also comprises means for detecting the connection quality of each antenna and a selection algorithm that continuously selects the antenna that provides the best connection.

In a preferred embodiment of the present invention, the antennas are dual-band antennas, both operating at more than one band of frequencies.

In a further embodiment of the invention, one or both antennas are implemented as external antennas. Single or dual-band antennas are also a possibility.

Figure 1 shows the preferred embodiment of the dual directive antenna system. Other more complex systems with PIN-diodes could be devised. One advantage of these systems is the possibility of using one antenna/resonator for both directions and thereby save space.

In a preferred embodiment, each of the antennas is having an antenna gain lower than 0 dB in most directions. However, when the dual antenna system is combined with a selection algorithm, which selects the antenna with the highest gain for each angle of orientation, the dual antenna system will have a gain higher than 0 dB in most directions.

It is a general rule of antenna design for handsets that the lower the volume of the antenna, the lower the efficiency. Therefore, if two antennas are implemented using the same volume as a single conventional patch antenna, both will have lower efficiency than a conventional one. In a dual antenna system, the handset will continuously select the antenna, which is less disrupted, as being able to choose between antennas is better than having only one which might be disrupted. Therefore, a dual directional antenna does not require more volume inside the housing than a single internal antenna to achieve better performance.

Fig. 2 shows the radiation characteristics of one directive antenna.

FIG. 3 shows the radiation characteristics of a preferred embodiment of the invention in which two directional antennas are arranged, pointing in opposite directions. It shows the directivity, in the horizontal planes, of each of the two antennas at one operational frequency band.

If the antenna arrangement is having more than one operational frequency band, each of the frequency bands will have a similar dual directivity.

It should be noted that the antennas complement each other as for instance a bad or critical transmission or receiving in the direction $\phi = 0°$ may be eliminated by switching to the other antenna.

FIG. 4 shows the circuit diagram of a dual antenna front end.

The output stage of the circuit comprises an amplifier 50 which may be coupled with two antennas 59a and 59b via an antenna switch 58, an electromagnetic coupler 51 and a selector switch 54. The electromagnetic coupler provides two separate outputs. One output to a power detector 52, TPD, and one output to a reflected power detector 57, RPD.

The circuit moreover comprises a low noise amplifier 56 which may also be coupled with the antennas 59a and 59b via the antenna switch 58, a bandpass filter 55 and a selector switch 54.

The circuit is in a transmitting mode when the selector 54 is in position 54a, and in receiving mode when the selector 54 is in position 54b.

The power detector 52, TPD, continuously measures the transmitted power from the power amplifier 50 of the output stage 50, while the power detector 57, RPD, continuously measures the power of the signal transmitted to the antennas 59a or 59b and reflected to the coupler 51.

The power detector may comprise a diode detector. However, according to the preferred embodiment of the invention, the power detecting means comprises a logarithmic amplifier. A logarithmic amplifier is preferable due to the fact that this detector may easily be integrated in the transceiver chip. The diode detector would typically have to be an external discrete component.

A method of measuring the transmitting quality, according to one embodiment of the invention, will now be described.

Under normal transmitting conditions, the impedance of the output stage will be matched with respect to the impedance of the connected antenna 59a or 59b in such a way that the reflected signal measured in 57 will be zero, or close to zero.

When the connected antenna 59a or 59b is completely or partly covered, the resulting input impedance of the antenna will change and the impedance matching of the antenna with respect to the impedance of the output amplifier will temporarily be lost. This lack of adjustment will result in the connected antenna 59a or 59b reflecting part of the incoming signal back to the amplifier 50.

This reflected signal will be detected by the power detector 57, and a bad transmission signal quality has thus been detected. It should be noted that the possibility to measure the transmitting quality is very advantageous, as the a transmitting estimate represents a very good estimate of the factual conditions because no diversity phenomena will interfere with the measurement.

It should nevertheless be noted that the transmissions signal quality may be determined in many other more or less convenient ways.

The measuring of the receiving quality may e.g. be obtained through a dynamically read-out of Rxqual values, such as bit error ratio, BER or frame error ratio, FER.

Rxqual, FER and BER are values determined in the GSM-standard.

FIG. 5 shows the flowchart of the algorithm for selecting which antenna to use as a transmitting antenna for the next transmitted burst. In a multiple band implementation, the transmission antenna for each band is selected separately by this algorithm.

The radiation properties of an antenna can be detected by applying two methods: One method during transmission and one during reception. To get the optimal performance, both methods should be used. The receiving and transmitting antenna may accordingly be selected independently.
During transmission, part of the transmitted power from the PA module 50 of fig. 4 will be reflected from the antenna. The amount of reflected power depends on how much the antenna is disrupted by the user.

Therefore, the choice of transmitter antenna is based on which of the antennas are reflecting less power.

In a conventional front end, both the transmitted and the reflected energy is also being detected. Therefore, the dual antenna system only increases the production price by the cost of the antenna selection switch 58.

The selection algorithm of the antennas has to be divided in two parts, one part that selects a TX antenna and one part that selects an RX antenna. The choice of antenna is

made on a burst to burst basis. The two parts of the algorithm works separately because the bandwidth of each antenna can be so narrow that it only matches either the TX or the RX band.

The flowchart of the selection algorithm for the transmission antenna is shown in figure 5.

The algorithm comprises four feedback loops in which a value determining the transmission quality CTX will be modified in dependence of the continuously measured reflected power.

Before the first burst is transmitted, a counter, CTX, is set to zero. Then, after each transmitted burst this counter is increased by a certain number in accordance with the reflected power. If little or no power is reflected from the input terminal of the antenna, the CTX is only increased by a small number. If the reflected power is less than 1 dB, the CTX will be remain unmodified. If more power is reflected, the counter CTX increases by a larger number. When the counter exceeds a certain limit, CTXmax, the other antenna is selected, and the counter is set to zero.

This algorithm ensures that if the radiation properties are very good for one antenna, this antenna will be used continuously. If the radiation properties are moderate for one antenna but even worse for the other, both antennas will be used over time, but the antenna with the better radiation properties will be used more frequently.

The algorithm ensures that both antennas are tested, but at the same time it also ensures that the handset does not toggle unnecessarily between the antennas.

FIG. 6 shows the flowchart of the algorithm for selecting which antenna to use as receive antenna for the next burst.

The algorithm is based on the same principles as the transmitting antenna selection algorithm described above, but, in this case, the assessment of a signal quality is based on existing parameters which derive from the GSM protocol.

During reception the RXqual for each burst is a clear indicator of the reception quality. Therefore, during reception, RXqual is used as a basis to select the antenna providing the better connection. RXqual is already used in conventional handsets as a basis for channel selection.

In the embodiment of the invention described above, a low quality of the reception or the transmission will cause a switching between the coupled antennas.

According to one embodiment of the invention, it should be noted that different antennas may be selected for receiving or transmitting purposes, respectively.

According to one preferred embodiment of the invention, one of the antennas 1, 2 is a directive antenna, said directive antenna being the preferred antenna. This means that the antenna is the main antenna, while the other antenna serves primarily as a fall-back antenna being selected only when absolutely necessary. Consequently, it is not absolutely necessary to obtain two antennas with equally high quality requirements, as the primary, and best antenna, is intended to be the most frequently used antenna.

It should moreover be noted that the invention focuses on the somewhat static transmission conditions due to the fact that the object of quality improvement relates to improvement of long-term use and disregards short-term transmitting/receiving interfering signal problems.

CLAIMS:

1. A mobile communication device having a housing (15), said device comprising antenna means and signal processing means coupled to said antenna means, said antenna means comprising at least two antennas (1, 2) having different radiation patterns,

at least two of said at least two antennas and the corresponding said signal processing means being adapted for transmitting and receiving electromagnetic signals.

2. A mobile communication device according to claim 1, characterised in that the at least two antennas operate at the same frequency bands.

3. A mobile communication device according to claim 1 or 2, characterised in that each of the at least two antennas have directive radiation patterns.

4. A mobile communication device according to claims 1 - 3, characterised in that at least one of the antennas is an antenna having a directive radiation pattern.

5. A mobile communication device according to claims 1-3, characterised in that the directivity of the at least two antennas (1, 2) are in opposite directions.

6. A mobile communication device according to claims 1-3, characterised in that the at least two antennas (1, 2) are omni-directional.

7. A mobile communication device according to claims 1-5, characterised in that the antennas are patch antennas (1, 2) arranged within the housing.

8. A mobile communication device according to claims 1-7, characterised in that the device comprises power detecting means (52, 53), said power detecting means being adapted to detect power reflected from at least one of the at least two antennas (1, 2).

9. A mobile communication device according to claim 8, characterised in that the power detecting means is connected to an electromagnetic coupler (51) coupled to an output stage (50) of said device,

said electromagnetic coupler (51) being connected to a power detector (52) adapted to measure the power of the transmitted signals from the output stage (50) to the antenna (1, 2) connected to said output stage (50),

said electromagnetic coupler (51) being further connected to a power detector (53) adapted to measure the power of the reflected signal from the antenna (1, 2) connected to said output stage (50).

10. A mobile communication device according to claims 1-9, characterised in that the device comprises switching means (58) coupled between said antenna means and said signal processing means, said switching means being adapted to switch automatically between the antennas (1,

2) of said antenna means in dependence of the detected power by said power detecting means.

11. A mobile communication device according to claims 1-10, characterised in that the power detecting means comprises a diode detector.

12. A mobile communication device according to claims 1-10, characterised in that the power detecting means comprises a logarithmic amplifier.

13. A mobile communication device according to claims 1-12, characterised in that the voltage of the diode detector (also the output of the logarithmic amplifier) is measured during the transmission bursts.

14. A mobile communication device according to claims 1-13, characterised in that Rxqual is used as an indicator of the degree to which the antennas (1, 2) are de-tuned.

15. A mobile communication device according to claims 1-14, characterised in that the antenna (1, 2) for transmission and/or reception is selected on a burst to burst basis.

16. A mobile communication device according to claims 1-15, characterised in that a counter for each C-tx is set to zero when a handset of said device is switched on, and each time there is a switch between the antennas.

17. A mobile communication device according to claims 1-16, characterised in that when the handset is switched on, a counter for each TX band and for each RX band is set to zero.

18. A mobile communication device according to claims 1-17, characterised in that the counter, C-tx, is increased by a number according to the amount of reflected power after each transmitted burst.

19. A mobile communication device according to claims 1-18, characterised in that when the counter, C-tx, reaches a number higher than a predetermined limit, C-tx-max, the counter, C-tx, is reset to zero, and the opposite antenna (1, 2) is selected for the next burst.

20. A mobile communication device according to claims 1-19, characterised in that it comprises means for evaluation of the receiving quality.

21. A mobile communication device according to claims 1-20, characterised in that the means for evaluation of the receiving quality comprises means for determining the Rxqual value of the received signal.

22. A mobile communication device according to claims 1-21, characterised in that the Rxqual value of the received signal is the BER or FER value.

23. Method of controlling switching means in a mobile communication device comprising antenna means and signal

processing means coupled to said antenna means, said antenna means comprising at least two antennas having different directivity patterns,

said switching means being arranged between said antenna means and said signal processing means in such a way that the switching means in each possible position (58a, 58b) are connected to one of the said at least two antennas (1, 2) and to said signal processing means, the method comprising the steps of

measuring the signal quality transmitted or received by the selected one of the at least two antennas (1, 2), and

switching the switching means to another possible position (58a, 58b) in dependence of the measured signal quality.

24. Method of controlling switching means in a mobile communication device comprising antenna means and signal processing means coupled to said antenna means, said antenna means comprising at least two antennas,

said switching means being arranged between said antenna means and said signal processing means in such a way that the switching means in each possible position (58a, 58b) connects one of the said at least two antennas (1, 2) to said signal processing means, the method comprising the steps of

measuring the transmitting and receiving quality of the signal transmitted or received by the connected of the at least two antennas (1, 2), and

switching the switching means to another possible position (58a, 58b) in dependence of the measured transmitting and/or receiving quality.

25. Method of controlling switching means in a mobile communication device according to claim 24, characterised in that the at least two antennas have different radiation patterns.

26. Method of controlling switching means in a mobile communication device according to claims 24 or 25, characterised in that at least one of the antennas is an antenna having a directive radiation pattern.

27. Method of controlling switching means in a mobile communication device according to claims 24-26, characterised in that each of the at least two antennas have directive radiation patterns.

28. Method of controlling switching means in a mobile communication device according to claims 24, 25, 26 or 27, characterised in that at least one of the antennas (1, 2) is a directive antenna, said directive antenna being the preferred antenna.

29. A mobile communication device having a housing (15), said device comprising antenna means and signal processing means coupled to said antenna means,

said antenna means comprising at least two antennas (1, 2) having different radiation patterns,

said device comprising means for evaluating the quality of the transmission from at least one of the at least two antennas.

30. A mobile communication device according to claim 26, characterised in that device comprises indication means, said indication means being adapted to provide a warning signal representing undesired transmitting conditions under certain predefined conditions.

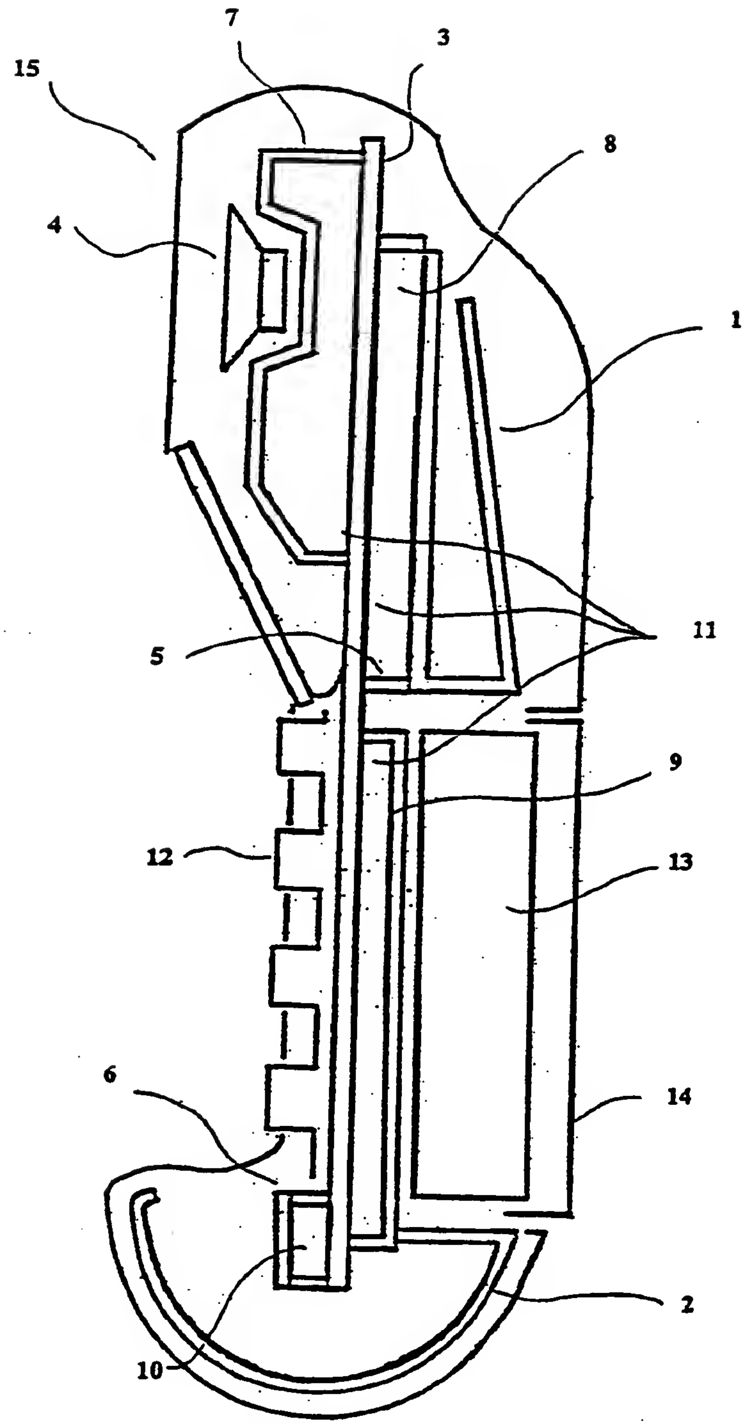


Fig. 1

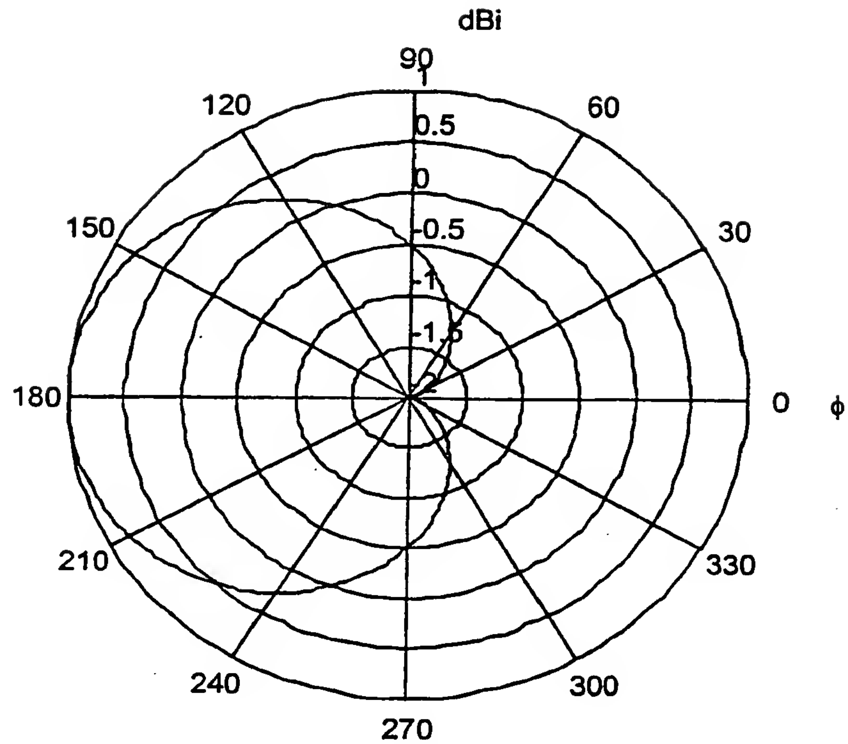


Fig. 2

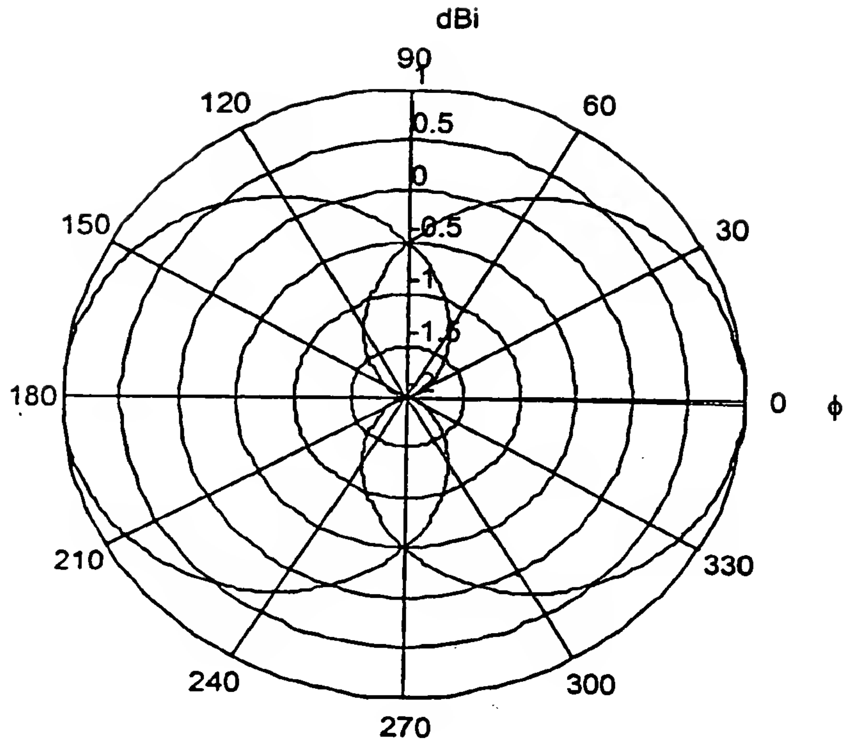


Fig. 3

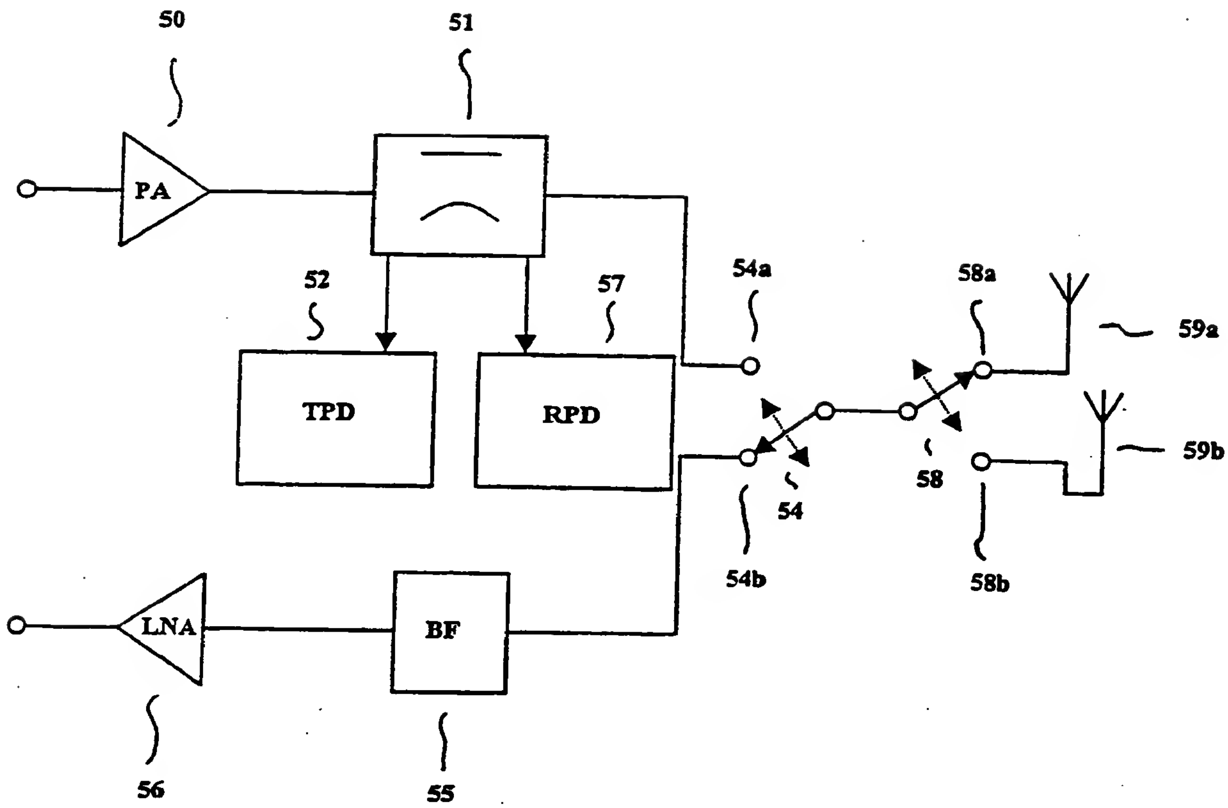
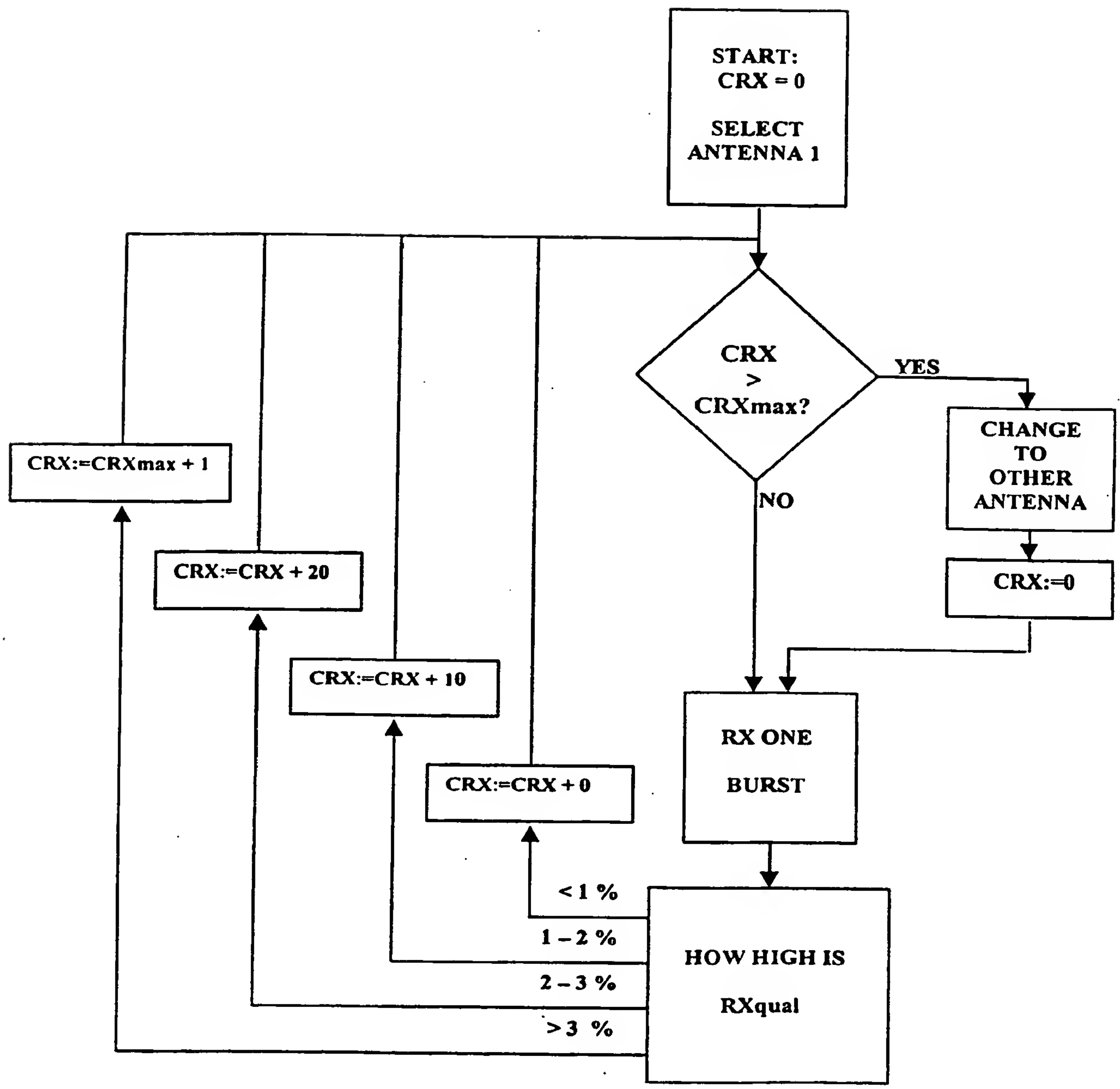


Fig. 4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CRX:=CRX + 0
RX ONE
BURST
HOW HIGH IS
RXqual
< 1 %
1 – 2 %
2 – 3 %
> 3 %

Fig. 6

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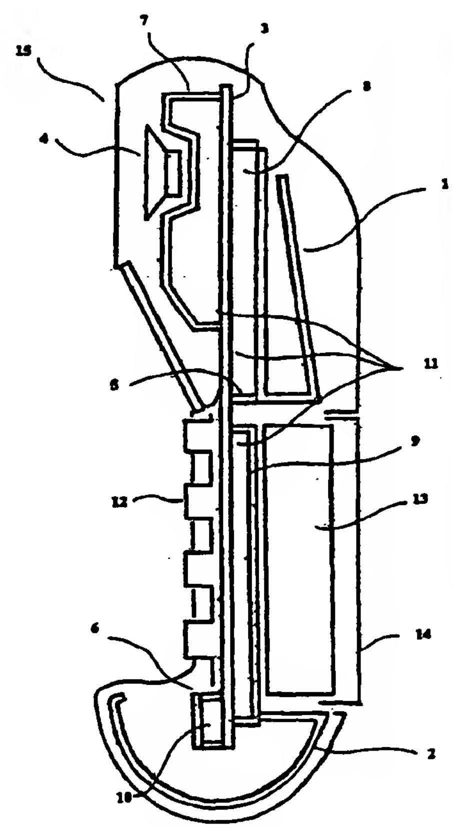
(57) Abstract

The invention relates to a mobile communication device having a housing (15), said device comprising antenna means and signal processing means coupled with said antenna means, said antenna means comprising at least two antennas (1, 2) having different radiation patterns. An important advantage of the invention is that the device may automatically select an antenna (1, 2) having a suitable radiation pattern for a particular environment.



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INTERNATIONAL SEARCH REPORT

International Application No
PC DK 99/00688

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/10 H04B1/38 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 633 519 A (GOTOH AKIO ET AL) 30 December 1986 (1986-12-30) column 1, line 55 - line 60 column 3, line 1 - line 8; figure 10 abstract ---	1-8,14, 20,21, 23-28
Y	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 01, 30 January 1998 (1998-01-30) & JP 09 247031 A (NEC CORP), 19 September 1997 (1997-09-19) abstract ---	1-8,14, 20,21, 23-28

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2000	27. 06. 2000

Name and mailing address of the ISA	Authorized officer
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PC)K 99/00688

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern al Application No
PCT/DK 99/00688

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